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NANODENTISTRY- A Review

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Abstract: Nanotechnology is the manipulation of matter on the molecular and atomic levels. Nanotechnology has changed the treatment strategy in the field of dentistry and medicine. Nanotechnology has several applications in the field of dentistry.
Keywords: Nanorobotics, Nanoencapsulation, Nano-orthodontics, Nanoimpression, Nanorobotic dentrifices.

I. INTRODUCTION

Nanotechnology also called as molecular engineering [1] is derived from the Greek word 'nanos' meaning dwarf [2]. This term was coined by Prof. Kerie E Drexler [3]. The concept of nanotechnology was based on the discussion in 1959 by renowned physicist Richard Feynman who described that it could be possible to directly manipulate the atoms [4].

Nanotechnology is defined as the science and engineering involved in the design, synthesis, characterization, and application of materials and devices whose smallest functional organization in at least one dimension is on the nanometer scale (one-billionth of a meter) [5],[6].

Nanotechnology has a lot of applications in diverse fields including medicine and dentistry.

II. NANO TECHNOLOGY IN DENTISTRY

A. Nanorobots

Nanorobots also known as nanites or nanomachines are microscopic devices that are measured on the scale of nanometres [7]. Nanorobots have the potential to induce oral analgesia, desensitize tooth, manipulates the tissues to realign and straighten irregular set of teeth and to improve durability of teeth [8]. Dental nanorobots are able to move through teeth and surrounding tissues by using specific movement mechanisms.

B. Nanocomposites

Nano technology in restorative dentistry has enabled the production of nano-dimesional filler particles which are added either singly or as nanoclusters into composite resins. Nanofillers can be prepared by techniques, such as flame pyrolysis, flame spray pyrolysis, and sol-gel processes [9]. The nanofillers used include an aluminosilicate powder with a mean particle size of 80nm and a 1:4 M ratio of alumina to silica and a refractive index of 1.508 [10]. This allows a greater amount of filler to be added into the composite resin matrix leading to the production of composites with a smooth surface after the polishing. Nano-composites are easy to shape with a high degree of strength and resistance to abrasion. Nano fillers being smaller than the wavelength of light have high translucency which allows generation of more aesthetic restoration [1]. Compared to conventional composites, nanocomposites have comparable or better finishing, polishing ability, shade matching, flexural strength and hardness. Nanocomposites defined by filler-particle sizes of ≤100 nm, can broadly be divided into nanohybrid and nanofilled resin-based composites [11].

Advantages [12],[21]

1) High filler loading
2) Desirable handling characteristics
3) High polish retention
4) Increased hardness.
5) Improved flexural strength, toughness and translucency.
6) Decreased polymerization shrinkage (50%).
7) Exceptional handling properties.

C. Nanoimpression

Nanofillers incorporated into vinylpolysiloxanes produce a distinctive material with improved flow, enhanced hydrophilic properties and superior detail precision. Example- Nano Tech Elite HD+ (High Intensity Resistance to Deformation) [13].

Advantages [14]

1) Excellent polishing ability and stain-resistant
2) Superb esthetics
3) Enhanced wear resistance and surface hardness
4) Better flow
5) Improved hydrophilic properties leading to fewer voids at margin and better model pouring.Enhanced detail precision.

D. Nanosolution (Nanoadhesives)

Nanosolutions are constituted by dispersible nanoparticles which can be added to various solvents, paints and polymers in which they are dispersed homogenously. In dentin bonding agents (Adper TM) they provide better dentin bond strength and better performance [13]

Advantages [15],[16]

1) Higher dentine and enamel bond strength
2) High stress absorption
3) Longer shelf life
4) Durable marginal seal
5) No separate etching required
6) Fluoride release

Trade name: Adper Single Bond Plus Adhesive Single Bond

E. Nanoencapsulation

Specifically targeted release systems have been developed by South West Research Institute (SWRI) systems that encompass nanocapsules including novel vaccines, antibiotics and drug delivery with reduced side effects. Future specialized nanoparticles could be engineered to target oral tissues, including cells derived from the periodontium. In 2003, Osaka University in Japan made possible the targeted delivery of genes and drugs to human liver [16],[17]. Several other products have also been developed by SWRI: [18],[21]

1) Protecting outfit and mask, incorporating antipathogenic nano-emulsions and nano-particles.
2) Medical appendage for immediate cure.
3) Bone targeting nano-carriers [19]
4) Wound dressings with silk nano-fibres in development.
5) Nanocrystalline silver particles with antimicrobial properties on wound dressings. (Acticoat TM, UK) [21].

F. Nanorobotic Dentifrices

Nanorobotic dentifrices made up of nanosized hydroxyapatite molecules are introduced into mouth by mouthwash or tooth paste. They metabolize trapped organic matter into harmless and odourless vapours and perform continuous calculus debridement. Nanorobotics dentrifices cover the sub gingival surfaces as well as identify and destroy pathogenic bacteria existing in the plaque and elsewhere [20]. They form a protective shell on tooth surface and may even repair damaged areas. Nanorobots (dentifrobots) left by mouthwash or toothpaste on the occlusal surfaces of teeth can clean organic residues by moving throughout the supragingival and subgingival surfaces, continuously preventing the accumulation of calculus [21].

G. Nanomaterials for Periodontal Drug Delivery

Hollow spheres, core-shell structure, nanotubes and nanocomposites have been developed for controlled drug release. Nanospheres composed of a biodegradable polymer allow for timed release of the drug as the nanospheres degrade facilitating site-specific drug delivery [18]. Recently triclosan-loaded nanoparticles prepared using poly (d,l-lactide-coglycolide), poly(d,l-lactide) and cellulose acetate phthalate were found to be effective in achieving reduction of inflammation [22],[23]. Tetracycline incorporated into microspheres is available as Arestin for drug delivery by local means into periodontal pocket [24]

H. Bone Replacement Materials

Bone is a natural nanostructure made up of organic compounds (mainly collagen) toughened with inorganic compounds like hydroxyapatite. Materials which can be used for bone graft should be osteoinductive, synthetic, non-sintered, extremely porous and nano-structured [10].

Nowadays alloplastic bone grafts are being developed with nanoscale particles. Nano-HAP (n-HAP) bone grafts, which are available in crystalline, chitosan-associated and titanium-reinforced forms is one such type of bone graft. These n-HAP composite bone graft scaffolds are highly biocompatible, have superior mechanical properties, and induce better cellular responses compared to 'plain' chitosan scaffolds [25],[26]. Calcium sulphate being biodegradable and osteoconductive bone substitute has also been utilized since 1892 [27],[28]. Calcium sulphate degradation leads to formation of calcium phosphate which helps in the attachment of osteoblasts and new bone deposition. Nanosized crystals of conventional Calcium sulphate bone grafts with particulate sizes ranging from 200-900 nm results in a graft material which is more resistant to degradation and lasts longer (12-14 weeks) than conventional Calcium sulphate (4-6 weeks). Nanocalcium phosphate, walled carbon nanotubes, and zinc oxide (ZnO) nanoparticles are impregnated into an alginate polymer matrix to develop an antibacterial nanoceramic composite material [29]. This material enhances HAP formation in bone defects. Nanoparticulate bone grafts are used in postextraction ridge preservation, intrabony defects regeneration, root perforations, sinus-lift procedures, implant dehiscence, and fenestration corrections [29].

I. Local Anesthesia Induction

In the era of nanodentistry, nanorobots will play a powerful role in the induction of local anesthesia. A colloidal suspension containing millions of active analgesic micron-size dental robots will be instilled on the patient's gingiva. The nanorobots reach dentin by migrating into the gingival sulcus and pass painlessly through the lamina propria or the 1 to 3µm thick layer of loose tissue at the cemento-dentinal junction. On reaching the dentin, the nanorobots enter dentinal tubule holes that are 1 to 4 µm in diameter and proceed toward the pulp, guided by a combination of chemical gradients, temperature differentials and even positional navigation. Once installed in the pulp, they establish control over the nerves, all under the control of the onboard nano-computer, as directed by the dentist. After oral procedures are completed, the dentist orders the nanorobots to restore all sensation, to relinquish control of nerve traffic, and to egress from the tooth by similar pathways used for ingress [30],[31].

J. Implants

Surface modifications of dental implants using nanotechnology helps to improve surfaces properties such as chemistry and roughness which play a determinant role in achieving and maintaining the long-term stability of implants in bone tissue. Nanoscale deposit and calcium creates a more complex implant surface for odontoblast formation. Direct bone-to-implant contact is desired for a biomechanical anchoring of implants to bone rather than fibrous tissue encapsulation [32]. Biologically active drugs such as antibiotics or growth factors can be incorporated in the implants. eg: Nanotite™ Nano-Coated Implant.

Recently three nano-structured implant coatings are developed:

•Nanostructured diamond: They have ultrahigh hardness, improved toughness over conventional microcrystalline diamond, low friction, and good adhesion to titanium alloys [33].

•Nanostructured processing applied to hydroxyapatite coatings: This is used to achieve the desired mechanical characteristics and enhanced surface reactivity and has been found to increase osteoblast adhesion, proliferation, and mineralization [33].

•Nanostructured metalloceramic coatings: These provide continuous variation from a nanocrystalline metallic bond at the interface to the hard ceramic bond on the surface [33]

K. Nanofilled Resin Modified Glass Ionomer

Nano-filled RMGI restorative material based on a prior RMGI with a simplified dispensing and mixing system (paste/paste) that requires the use of a priming step, but no separate conditioning step has been introduced for restoration of primary teeth and small cavities in permanent teeth. Its primary curing mechanism is by light activation, and no redox or self-curing occurs during setting. This material allows a highly packed filler composition (69%), of which approximately two-thirds are nano- fillers [34].

L. Nano-Orthodontics

Orthodontic nanorobots could directly manipulate the periodontal tissues including gingival, periodontal ligament, cementum and alveolar bone allowing rapid and painless tooth alignment, rotating and vertical tooth repositioning within minutes to hours [35]

M. Nano-Coated Orthodontic Archwires

A recent innovation in the form of metal nanoparticle coating has been introduced that significantly reduces friction of various surfaces including archwires. The coating consists of electrodeposited Ni film impregnated with inorganic fullerene-like nanospheres of tungsten disulphide [36].

N. Orthodontic Brackets

A new material which contained polysulfone embedded with hard alumina nanoparticles was developed in the year 2012 by UC3M for making orthodontic brackets. The rigidity of the material increases the strength of the brackets. This material reduces frictional and mechanical resistance of the brackets to orthodontic wires along with maintaining the transparency of the brackets [37].

III. CONCLUSION

Nanotechnology is a new and exciting area of science with a significant potential to yield new generation of technologically advanced clinical tools and devices for oral health-care. Nanotechnology involves manipulation of matter at the molecular level, including individual molecules and the interactions among them. Nanodentistry will give a new vision to comprehensive oral health care, as now trends of oral health have been changing to more preventive intervention than a curative and restorative procedure. It will be of prime help for dentists practicing both conventional and four handed dentistry. However, still further research needs to be done.

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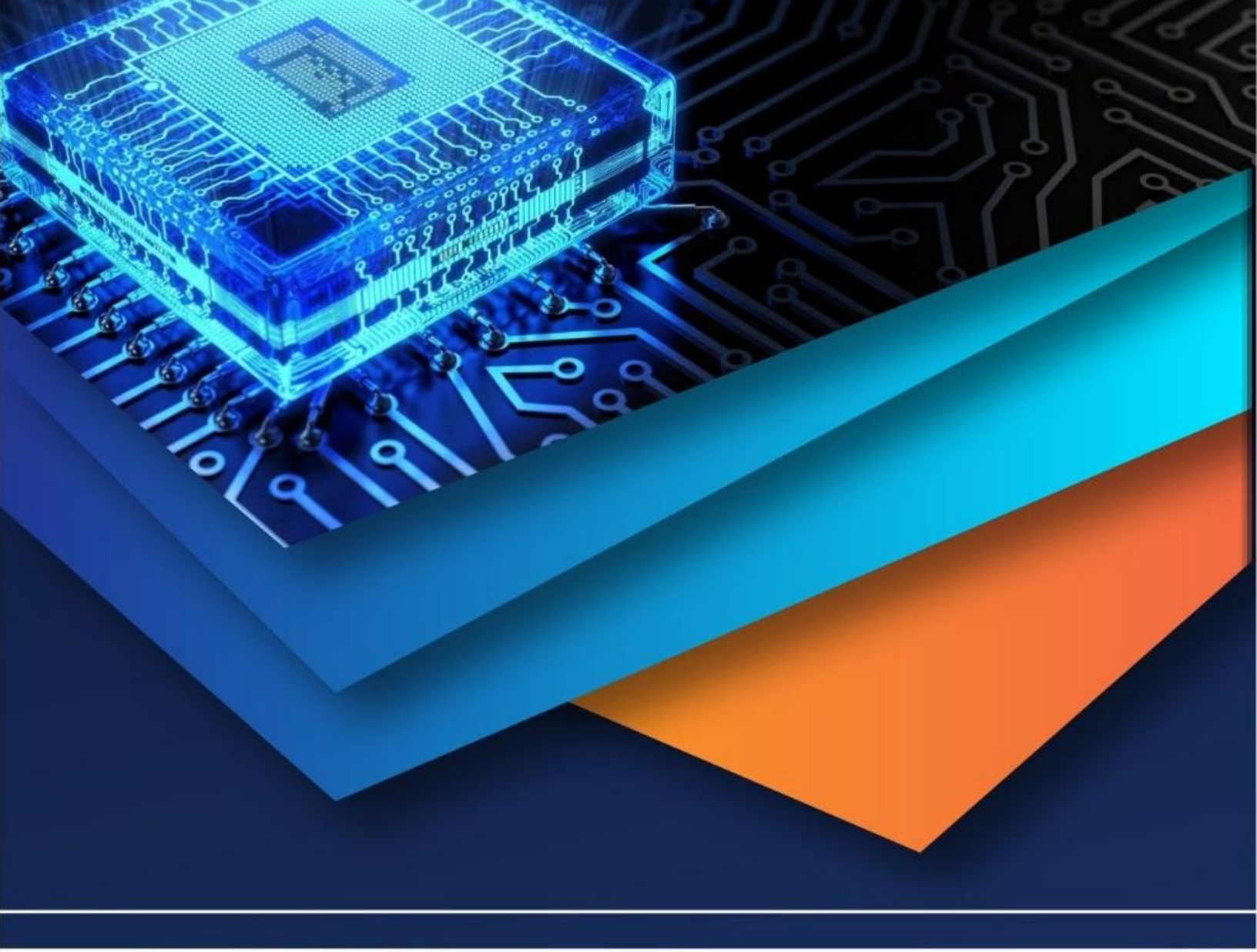

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